WHAT I THOUGHT YOU SAID WHEN I ASKED YOU WHAT YOU THOUGHT

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ABSTRACT: The expert system within OASIS, the advisory program for the operation of water control structures within the South Florida Water Management District, contains the operating guidelines for the District's water control facilities as well as information on field conditions. After an inventory of documented operating guidelines was conducted, the domain experts, in this case the water control operations decision makers, were interrogated during structured interviews. These sessions focused on decision factors, operating modes, data sources, and expected outcomes of operations for operations within a prototype region of the District. Information from these interviews were encoded in the expert system, the experts evaluated the accuracy, consistency and comprehensiveness of the knowledge base. Discrepancies and other conclusions of the evaluation were investigated, and revisions were incorporated and subsequently re-evaluated through this iterative process. The completed expert system prototype will be evaluated extensively during a 12-month period in daily operation.

INTRODUCTION

The South Florida Water Management District (District) operates more than 200 water control structures along 2000 miles of primary canals within its 18,000-square mile domain. Seasonal demand for agricultural and municipal water supply, year-round flood protection and protection of coastal well fields from salt water intrusion, environmental quality enhancement, as well as site-specific legal and other constraints, combine to create a very complex decision making arena for the Operations staff at the District. The possible combination of operations for the more than 500 gates and almost 100 pumps is astronomical. The task of making the appropriate water management decisions from among the possible permutations requires two full-time experts, a support staff of approximately 50 to 100 full time employees, and an extensive data acquisition and supervisory control system. The primary domain expert is Richard Slyfield, Director of the District's Operations Division; George Hwa is the Assistant Director of the Operations Division, and together, these two experts have over twenty years of experience in making operation decisions for the District. The experts use a combination of empirically-derived heuristics and hydraulic operating guidelines which rapidly reduce the countless possibilities down to a few appropriate solution paths.

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The District is developing a comprehensive decision support system to aid in the operation of its water control structures. The Operations Assistant and Simulated Intelligence System (OASIS) will monitor and display real-time hydrologic and meteorologic data and structure status, provide multiple levels of current and projected high and low water alarm detections, incorporate a versatile data plotting package, and features an operations advisor expert system.

ACQUIRING DOMAIN EXPERTISE

The knowledge base for the District's water control operations is comprised of static, dynamic and procedural information. Static domain knowledge contains physical system components, hydraulic characteristics, and other features that are relatively invariant over time. The dynamic component of the knowledge base includes hydrologic and meteorologic data collected in the field and transferred to the control room, policy decisions which influence daily operations, coordinated activities with internal and external groups, weather forecasts, antecedent rainfall conditions, and notices from the public. Procedural knowledge includes the hydraulic operating guidelines, empirical relationships, heuristics, operating constraints brought about by physical limits of the system, as well as fundamental domain principles, e.g., open channel flow relationships, and the analytical tools used by the experts to reach decisions.

Knowledge acquisition is the process of eliciting and encoding domain expertise from human experts and other knowledge sources, typically through a combination of observation, structured interviews, and research. During the development of OASIS, the objective was to document the decision making algorithms used by the experts, including enumerating the relevant decision factors and resources utilized by the experts. A major challenge was how to express the decision making algorithms, procedures that may have taken years of training and experience to acquire and utilize, in a way that was lucid enough for a nonexpert to grasp, could be encoded in an appropriate computer representation, and yet retain the accuracy, efficiency, consistency, and comprehensive characteristic of the domain experts. This challenge and other components of the knowledge acquisition process encountered during the development of the expert system within OASIS are addressed below. Throughout this paper, the term knowledge engineer is used when referring to the individual which interacted with the expert during the knowledge acquisition process.

STRATEGY FOR COMPILING KNOWLEDGE

The goals of the knowledge acquisition process were to address the following issues.

1. How does the expert assess the situation?
2. How does the expert recognize that a problem exist?
3. How does the expert define (and investigate) the problem?
4. What is the appropriate strategy to solve the problem?
5. What are the appropriate decision factors, and how are their values

determined?
6. Identify and inventory the data and rules used by the expert.
7. Identify the tools used in the decision process.
8. Identify other people or agencies involved in the decision.
9. What is the time frame of the decision process?

Five loosely-defined techniques were utilized in the knowledge acquisition process, with each addressing one or more of the aforementioned goals:
1. Familiarization of the domain by the knowledge engineer;
2. Observation of the experts in action;
3. Detailed problem analysis (interviews);
4. Experts' evaluation of progress, and;
5. Knowledge base verification.

Familiarization.- A preliminary component of the knowledge acquisition process was for the knowledge engineer to gain as much insight into the domain as practicable. This was accomplished in part through observation of the experts as they evaluated situations, accessed data and relevant operating manuals, utilized appropriate analysis tools, and conferred with other individuals and agencies involved in the decision making process. In addition, a significant amount of procedural knowledge was obtained from the hydraulic operating guidelines developed during the design and subsequent operation of the District's water control facilities. Daily operations logs, structure status information and hourly water levels are maintained by control room personnel, providing convenient access to field conditions and operational activities. Review of these documented examples provided a tangible basis for the future evaluation of the District's water management operations. Additional perspectives on the decision process were obtained through discussion of the operations with individuals other than the domain experts, e.g., District management and staff of projects affected by daily operational decisions.

Observation.- A principal step in the knowledge compilation process was documented observation of the experts in action. While passive, i.e., uninterrupted, observation is suggested by some expert system developers, often times decisions were based on subtle factors which required more thorough explanations. The experts were observed throughout the duration of the prototype development. Primary facets of the decision making algorithms included the type and priority of different data, the experts' working environment, what data are used most, who does the expert confer with, what are the steps in the many types of operational decisions, what data format is most convenient for the expert, what type of interface capability is needed, what is the time frame for decisions, and how do the experts deal with data uncertainty, e.g., inaccurate, inconsistent, or incomplete data.

Interviews.- After several weeks of observation and an inventory of documented operating guidelines was conducted, the existing domain experts were interrogated during structured interviews. The interviews focused on decision factors, operating modes, data sources, and expected outcomes of operations for a prototype region of the District. Selected combinations of hydrologic and meteorologic conditions were examined. These combinations were specific enough for

the experts to focus their attention, yet diverse enough to cover all practicable ranges of conditions. The main instrument used during the interviews was a matrix of decision factors, with each unique permutation specifying an appropriate set of water control operations. A challenging variety of conditions was evaluated during each interview, resulting in intense 1-3 hour sessions. During the interviews the experts collaborated for accuracy and clarity of their response. As a supplement to the experts' interrogation, the daily operations logs and hourly records provided examples and further clarification of the operation rules.

Some general operating guidelines were enumerated, however, the majority of the water control operations depend on specific conditions and could not be generalized. The knowledge base expanded more rapidly as the general guidelines were extrapolated to undocumented operations, in contrast to incorporating specific rules with unique decision factors.

Experts' Evaluation.- After the information obtained from these interviews were encoded in the expert system, the experts evaluated the accuracy, consistency, and completeness of the OASIS knowledge base. Discrepancies and other conclusions of the evaluation were investigated and revisions were incorporated and subsequently re-evaluated through this iterative process.

Prototype Verification.- The completed expert system prototype will be evaluated extensively by the experts during a 12-month period in daily operation. Evaluation criteria will include accuracy, consistency and completeness of operations advice, suitability to operations decisions, performance speed, and user interface.

SUMMARY AND CONCLUSIONS

The expert system within OASIS, the advisory program for the operation of water control structures within the South Florida Water Management District, contains the operating guidelines for the District's water control facilities as well as information on field conditions. After an inventory of documented operating guidelines was conducted, the domain experts, in this case the water control operations decision makers, were interrogated during structured interviews. These sessions focused on decision factors, operating modes, data sources, and expected outcomes of operations for operations within a prototype region of the District. Information from these interviews were encoded in the expert system, the experts evaluated the accuracy, consistency and comprehensiveness of the knowledge base. Discrepancies and other conclusions of the evaluation were investigated, and revisions were incorporated and subsequently re-evaluated through this iterative process. The completed expert system prototype will be evaluated extensively during a 12-month period in daily operation.